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Final Report

for

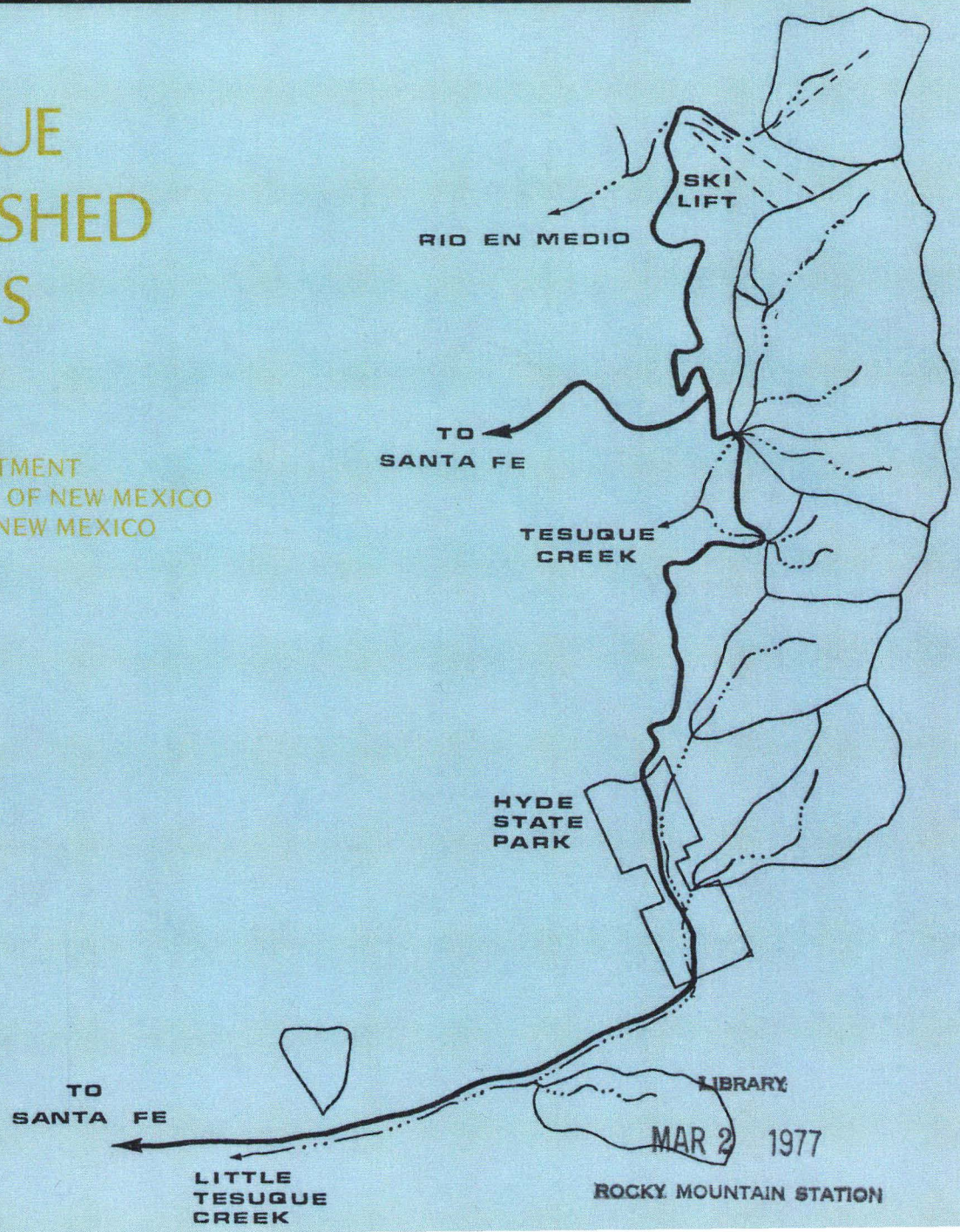
Effects of ski area use on

biological and heavy metal aspects

of water quality

TESUQUE WATERSHED STUDIES

BIOLOGY DEPARTMENT
THE UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NEW MEXICO



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Final Report

for

Effects of ski area use on biological and heavy metal aspects of water quality

Cooperative Agreement 16-520-CA (EC-159)

by

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University of New Mexico

January 1977

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INTRODUCTION

Public recreation is one part of the multiple land-use management concept currently used for the National Forests. Ski areas are fast becoming areas of high density winter recreation. The ski areas are often located in high mountains which provide watersheds for lower elevation municipalities or agricultural areas. High density recreation in the mountain areas could potentially degrade both the chemical and bacteriological quality of the streams originating in those areas.

Sanitary factilities for the high density ski areas are a potential source for degradation of bacteriological water quality. Sanitary facilities must be adequate to handle peak periods without affecting the bacteriological quality, or significant health problems could occur for concurrent users of the stream water.

Chemical water quality could potentially be degraded as a result of many factors. Initial construction of facilities, trails and access roads could alter the water quality. Sanitary facilities, slopes that are not revegetated, road maintenance programs such as salting to provide winter access, and increased air pollution from associated automobile activities could result in prolonged sources of degradation of water quality.

The present study was undertaken to determine if there presently is any degradation of water quality resulting from the activities associated with a ski area in a high mountain watershed, the Santa Fe Ski Basin. The primary focus of the study was on

the heavy metal aspect of chemical water quality and the sanitary health aspect of bacteriological water quality. The bacteriological aspects were coordinated with a similar study conducted by Quentin D. Skinner and John C. Adams (1976) on a watershed in the Medicine Bow National Forest.

STUDY AREA

The Santa Fe Ski Basin is located in the Santa Fe National Forest about 15 km northeast of Santa Fe, New Mexico. The basin was separated into three regions for purposes of stream water collections (Figure 1). The portion of the stream above the ski lodges and associated sanitary facilities was used as the control and will be referred to as Area 1. Area 2 is the drainage area for most of the ski runs plus two chair lifts, a parking lot, drainfields from the waste disposal systems of two lodges, and 0.8 km of road subject to road salting practices. A stream diversion, consisting of a gate dam and underground pipe, diverts the stream from Area 1 out of the study area. Therefore, water quality data collected from Area 2 reflect impacts on that area only. Area 3 is the lower portion of the ski basin which does not have skiing activity; however, it is affected by a parking lot and 0.5 km of road subject to road salting practices.

Method and Procedures

Triplicate water samples for each bacterial analysis were collected from the base of Areas 1, 2 and 3 on a biweekly basis

from July 1975 through June 1976. The triplicate samples were taken in as rapid succession as possible, iced, and transported to Albuquerque for analysis. All samples were processed within four hours of collection.

Total coliforms were enumerated using the membrane filter technique described by Standard Methods (Amer. Public Health Assoc. 1971). M-Endo medium (BBL) and 0.45 micrometer filters (Millipore) were used. Incubation was in a water bath at $35 \pm 1^{o}C$ for 24 hours.

Fecal coliforms were enumerated using the membrane filtration technique described by Standard Methods, m FC broth (Difco), and 0.45 micrometer filters (Millipore). Incubation was in a water bath at $44.5 \pm 0.2^{o}C$ for 24 hours.

Fecal streptococci were enumerated using the membrane filtration technique described by Standard Methods, KF streptococcus agar (Difco), and 0.45 micrometer filters (Millipore). Incubation was in a water bath at $35 \pm 1^{o}C$ for 48 hours.

Stream samples for heavy metal analyses were collected in one liter amber linear polyethylene bottles at all three locations. The entire sample was filtered through a 0.45 micrometer cellulose membrane filter. The filtrate was analyzed by atomic absorption spectrophotometry with no further preparation. The filter was digested in equal volumes of HNO_3 and HCl (Anderson 1974), brought up to a final volume of 25 ml and analyzed.

Lichen samples (Usnea sp.) were collected around the parking lot and along the main road at the ski basin and from a control spruce-fir forest near the summit approximately 3.5 km away. The lichen samples were digested with HNO_3 and HCl and analyzed.

Snowpack samples were taken on a monthly basis at five locations throughout the ski basin watershed and at the control area. Snowpack samples were taken once on March 13, 1976, radiating out from the parking lot at equal distances in four directions. A standard U. S. Department of Agriculture Snow Survey corer was used for the snowpack field measurements and to collect profiles of the snowpack for heavy metal determinations. The profile was transferred from the corer to linear polyethylene bottles and the thawed sample processed in the same manner as the stream heavy metal samples.

Zn, Pb, and Cu analyses were performed on a P-E Model 306 Atomic Absorption Spectrophotometer equiped with a HGA 2100 Heated Graphite Furnace and Deuterium Background Correction.

Analysis of Variance and Duncan's New Multiple-Range Test were employed in data analysis. Data anlyses were organized in the same fashion as that of Skinner and Adams (1976) to afford the best comparison of data.

RESULTS AND DISCUSSION

Bacteriological Water Quality

Stream water collections were started on June 26, 1975, and continued through June 21, 1976. Samples were analyzed

for total coliform, fecal coliform, and fecal streptococci. Samples collected before September 8, 1975 were analyzed for only total coliform (Tables 1, 2, 3).

A two-way Analysis of Variance (Table 4) gave highly significant F-values for differences between sites, dates, and the site X data interaction factor for all three bacterial groups. Duncan's New Multiple-Range Test was then employed to separate the factors and identify the locations and dates which were different (Tables 5, 6, 7, 8). All Duncan's New Multiple-Range Tests in this report use P = 0.05 level of significance.

The site and bacterial group analysis (Table 5) revealed the control area (Area 1) to be significantly lower than both Areas 2 and 3 for total coliform, significantly higher than Area 3 for fecal coliform, and not significantly different than Areas 2 and 3 for fecal streptococci. The total coliform data is as one would expect if there was any impact from the ski basin. However, the fecal coliform and fecal streptococci data do not follow the same pattern established by the total coliform data.

Geldreich and Kenner (1969) looked at fecal coliform to fecal streptococci ratios to characterize bacterial colonies from various mammalian sources. Human feces were found to have F.C./F.S. ratios of 4.4/1, while other mammalian species were found to have F.C./F.S. ratios of from 0.4/1 to 0.02/1 and ratios for poultry species were 0.6/1 to 0.4/1. The F.C./F.S.

ratios found at the Santa Fe Ski Basin were 0.147/1 for Area 1, 0.029/1 for Area 2, and 0.030/1 for Area 3. If there was a direct addition of raw sewage from the ski basin, then one would expect an increase in fecal coliform to fecal streptococci and an increase in total numbers in relation to the control (Area 1) when in fact the opposite occurred. The literature on fecal pollution does reveal a few possible explanations for the apparently contradictory results.

Certain species of Aerobacter associated with mammalian feces do exhibit differential rates of mortality with time and some even exhibit "bloom" type of activities. These Aerobacter species are known to show as coliform colonies in the total coliform analysis. If such multiplication or bloom occurred at the Santa Fe Ski Basin sewage system, this would explain the significantly higher total coliform levels at Area 2 and Area 3 in relation to Area 1.

The F.C./F.S. ratios given by Geldreich and Kenner (1969) apply to colonies cultured from direct feces collections or from raw sewage, municiple,or agricultural water. The possibility of differential mortality rates for fecal coliform and fecal streptococci could result in drastic changes in the resultant ratios. As a result, the bacterial colonies could reflect only the result of time of exposure to the environment and could lose all similarities to the original colonies. Therefore, all implications as to the potability of the water with respect to pathogens could also be lost.

The literature has also eluded to the differential effect of total salts and nutrient content of water resulting in differential mortality rates of bacterial colonies. The general trend appears to establish that bacterial colonies survive better and for longer periods of time in water of higher total salt concentrations, and generally do not multiply in polluted or nutrient rich water (Geldrich and Kenner, 1969). Area 1 is very good quality water and is very low in total salts. Area 2 and Area 3 are higher in both total salt and nutrient concentrations (Gosz, 1975), and both of these aspects of water quality would lend more stability to the bacterial colonies in relation to Area 1. Cold temperatures of mountain streams receiving bacterial pollution tend to increase the survival for fecal coliform bacteria (Flack, 1976) and therefore, could further stabilize the colonies found in the streams.

Perhaps the most important analysis of the bacteriological water quality data is the relative numbers found at the Santa Fe Ski Basin in comparison to similar areas. Skinner and Adams (1976) found fecal coliform and fecal streptococci levels in their control, or above the ski area, very similar to the levels found at the Santa Fe Ski Basin. However, below the ski area, levels were in the thousands of colonies and the F.C./F.S. ratio of collections in February, March, and April averaged 0.868/1. The effluent from the sewage treatment plant at the ski area in the Medicine Bow National Forest had an average F.C./F.S. ratio of 1.29/1. This same ratio was

reached periodically in the stream samples below the treatment plant. The Santa Fe Ski Basin employs a drainage field for their sewage disposal and no samples were ever taken directly from the drainfield tiles. However, the ratio of F.C./F.S. decreased in the treatment areas in relation to the control at the Santa Fe Ski Basin, whereas the ratio increased at the treatment location in relation to the control at the Medicine Bow National Forest ski area, as did the total numbers.

An important aspect of the bacteriological water quality data is the relationship of the colonies found and the usage of the ski basin. Tables 6, 7, and 8 show the significance of the date factor in the analysis of variance. The dates are ranked with the highest mean given the rank of 1. The only dates which were significantly higher than the other dates for total coliforms occurred before or on November 17, 1975 with the highest values in the summer months. Only November 3, 1975 was significantly higher in fecal coliforms. September 8, September 22, November 3, and December 8, 1975 were the only dates significantly higher in fecal streptococci.

The Santa Fe Ski Basin did not open until December 3, 1975, and closed on April 4, 1976. The heaviest use of the ski area occurred on December 26 and 27 on a per vehicle basis, but the month of February had the heaviest total use of any month (Table 9). The average number of skiers per day for the 75-76 ski season was the highest on record (Table 10). However, the only collection to be significantly higher during the period of skier

usage was December 8, 1975 and this date was only higher for fecal streptococci. The main periods with the highest coliform counts occurred during the summer and fall months.

Heavy Metal Analyses

Snowpack Samples:

The monthly snowpack samples were collected at five locations throughout the ski basin watershed and at two control areas located near the summit (Table 11 and Figure 2). The samples were analyzed for total particulate matter, Zn, Pb, and Cu. The Analysis of Variance of the monthly snowpack samples is shown in Table 12. All F-values for the given metals were found to be non-significant at the $P \leq 0.05$ level. Duncan's New Multiple-Range Test was employed to determine if any individual values were significantly different, and this test showed no values to be significantly different than any other. (Table 13).

A closer examination of the heavy metals and particulate content of the snowpack reveals some unexpected values. The total g/ha inputs for the metals and total particulate matter are often times higher in the control areas than in the locations throughout the ski basin. The snowpack at the control area was much deeper than the areas located in the ski basin, which could explain the higher total g/ha input of the metals and particulate matter. However, looking at the levels of the metals and particulate matter on a µg/l basis, which would negate differences in total snowpack, still reveals very similar

concentrations at all locations.

Schlesenger and Reiners (1974) studying deposition of cations in water in the New England mountains found a weighted average concentration of 40 µg/l for Pb, which fell between the values of 1.6 µg/l for relatively clean California air (Chow and Johnstone, 1965) and the very high levels of 100-490 µg/l for urban areas (Ettinger, 1966). Levels found at all locations in the Santa Fe Ski Basin were very similar to the 40 µg/l level at the end of the snow accumulation period. Schlesenger and Reiners estimated the total per annual input of Pb to be approximately 20 mg/m^2. Transforming the data collected for the control areas at the Santa Fe Ski Basin yields a total input on an annual basis of 24 mg/m^2.

It should also be noted that the total particulate matter input on a kg/ha basis was found to be higher in the control area under the trees than the control area in the open; however, the total g/ha levels of the heavy metals were very similar between the two locations.

On March 16, 1976, samples were taken radiating out at about 60 m intervals in four directions from the parking lot located at the Santa Fe Ski Basin. These samples were analyzed for total particulate matter, Zn, Pb, and Cu (Table 14). The Analysis of Variance (Table 15) revealed that particulate matter did not vary with direction but was slightly affected by distance. Metal concentrations did not vary with direction but did with distance. There was a significant difference between

the different metals.

Duncan's New Multiple-Range Test was employed for each paired data (Tables 16, 17). This test did not reveal any difference between heavy metals and particulate matter content of the snowpack with direction from the parking lot. The only samples that were significantly different and higher with respect to distance were the Pb values obtained at the closest proximity to the parking lot, Cu values obtained at the closest proximity to the parking lot, and the particulate matter collected closest to the parking lot. One should remember that these data were obtained on only one date towards the end of snowpack accumulation. Visual observation of the relative mean values reveals a trend of all metals and particulate matter being the highest at the closest areas and grading to the lowest values at the farthest locations. This general trend does not hold for the particulate matter content where the farthest location has the second highest value. These locations often times were in the trees, and as shown by the control location on the monthly collections the tree samples often times had much higher particulate matter levels than did the control open location.

A trilinear plot of the relative concentrations of the heavy metal values provides a rapid method to observe differences between locations (Figures 3 and 4). The variability within a location is considerable and thus the data obtained in one year does not yeild a significant difference between locations.

Lichen Analysis:

Plants have commonly been used as indicators of heavy metal pollution. Rolfe (1974) analyzed tree rings to detect the accumulation of lead over a period of time. He found significantly higher lead levels in the last 10 years growth of trees nearer highways. Lichens such as Usnea, an epiphyte growing attached to the tree bark, obtains all of its nutrients from the atmosphere. Thus, species of Usnea (a lichen commonly associated with the spruce-fir vegetation of the region) perhaps could provide such a biological indicator.

Usnea samples were collected at the control area (the same control area as for the snow samples) and roadside areas near the ski basin lower parking lot. The roadside area samples would provide the treatment factor for possible impact of automobile activity near the ski basin. Triplicate samples from both the control and roadside areas were digested and analyses were performed for Mn, Zn, Pb, and Cu (Table 18). Statistical analyses (employing the use of paired mean values to attain a t-value) reveal no significant differences between any of the metals analyzed. However, Pb did not follow the same pattern for Mn, Zn, and Cu. Lead was the only metal which was higher in concentration in the roadside samples than in the control samples. Looking at the relative level of Pb in comparison to the other heavy metals (the mean Pb value divided by the sum of the mean values of all metals) did yield a significant t-value for the difference between Pb and the

other elements. This should represent the relative total change in Pb values and appears to provide a much more sensitive measure of the changes in Pb concentrations. A larger sample size may yield significant differences in any or all comparative paired means.

The trilinear plot of Zn, Pb, and Cu values gives distinct separation of sample locations (Figure 5). Thus, Usnea may provide a valuable biological indicator of long term pollution and appears to reduce the variability found in any single year.

Water Samples:

Water samples for heavy metal determinations were collected at the three locations on 34 different dates throughout the year. Samples were analyzed for total particulate matter, Zn, Pb, and Cu. Samples were filtered through a 0.45 micron cellulose membrane filter. Total particulate matter was determined by the weight gained by the cellulose membrane filter after filtration.

Tables 19 and 20 show the weighted average concentration (determined by multiplying the concentration by the discharge, summing all the resultant values and dividing by the total discharge) and the annual kg/ha removal from the three areas at the Santa Fe Ski Basin. Area 1 had the lowest concentrations for all constituents, Area 2 had the highest concentrations, and Area 3 showed a net gain of constituents (shown by a negative transport from this area) except for organic-N.

Area 1 and 2 had positive values demonstrating a total removal from the area, Area 1 being much less than Area 2 in all constituents except for organic-N.

The negative values shown on a kg/ha basis from Area 3 could possibly be explained by the sediment traps (logs placed across the stream in stair-step fashion) placed in the streambed between the sample locations for Area 2 and 3. These sediment traps provide for settling of particulate matter during the typical lower discharge regimes of the stream. It is our belief that during high discharge periods (such as the very rapid increase in discharge following summer thunder-showers), these basins would be cleaned out. If more high discharge periods had been measured, the total kg/ha export would not have been such a large negative number and perhpas be much closer to 0 or positive.

Of all the constituents measured, the particulate matter is of prime importance. As shown from the above data, although all constituents increased in Area 2 compared to Area 1, particulate matter had the highest relative increase and also controlled the increase shown on all the other metal constituents. This control can be demonstrated by the correlation coefficients shown in Tables 21, 22, and 23. In the control area (Area 1), the total particulate matter load of the stream was significantly correlated with copper in the filtrate (and as a result, also the total copper). The other particulate metals were not correlated with the total particulate matter and there was not

a significant correlation between any of the particulate metals. However, Area 2 showed a significant correlation between total particulate matter and all other constitutents except for filtrate Zn and filtrate Pb, and all of the total heavy metal inputs were significantly correlated with each other. The correlation did not hold as well for Area 3 as it did for Area 2 in all cases, but all of the particulate heavy metals and total particulate matter were significantly correlated with each other. Also looking at the ratios of the organic-N content and the particulate matter content at the three locations, one notices a dramatic decrease in the ratio of organic-N to particulate matter from Area 1 to Area 2, and a slight rise from Area 2 to Area 3. If all the particulate matter was of the same origin (meaning particulate mineral matter or particulate organic matter) the organic-N/particulate matter ratio would remain the same in all three locations. This drop noted in Area 2 for organic-N/particulate matter ratio demonstrates an increase in the mineral content in relation to the organic matter content. On an absolute kg/ha basis, all three areas showed a positive export of organic-N. Since the organic matter is much lighter in relation to the mineral matter, it tends to float and does not settle out in the basins below Area 2. This would explain the positive export shown in organic-N content while the metals show a negative export from Area 3.

The relative shifts of heavy metal content of the particulate matter between Areas 1, 2, and 3 shows an increase in the Zn

content and a decrease in Pb and Cu contents from Area 1 to Area 2 and to Area 3. This is what one would expect as the organic matter content decreases between the areas. Heavy metal data on typical granite material shows an average of 20 ppm Cu, 60 ppm Zn, and 20 ppm Pb (Graustein, personal communication). These are only averages, but they demonstrate Zn to be higher than Pb or Cu in a basic substrate granite. All of these above factors support the theory that there is a higher particulate mineral matter loss from Area 2 and this particulate matter loss accounts for the increased loss in Zn, Pb, and Cu from Area 2.

Similar increases in export of particulate matter after disturbances of forested ecosystems is common in the literature (Bormann, Likens, and Eaton, 1969; Bormann, et al. 1974; White, 1976; Megahan, 1972). The latter two reports found the majority of the particulate load after disturbance associated with road construction. There has been an increase in road construction at the Santa Fe Ski Basin associated with the increase in skiing activities and the increase of development of ski trails and lifts. These exposed areas could be the potential source of the increase in the particulate load in the stream below Area 2.

One other possible explanation for the particulate matter loss seen at Area 2 which merits mention is the addition of particulate matter in the road salt/sand deicing mixture. The normal application of 1,087 kg per km of road per application would contribute about 7 kg/ha of particulate matter smaller than ¼ inch dia. Nine salt/sand applications could account for the

additional transport of particulate matter at Area 2 in comparison to Area 1. The heavy metal content of the salt/sand mixture is not know, but it is possible the relative heavy metal content of the mixture is similar to that of the particulate matter in the stream. Road salt is definitely a contribution to inorganic nutrient loss from Area 2 and Area 3 (Gosz, 1975). However, it appears unlikely that all of the particulate loss can be explained by the road salt/sand applications because of the accumulation of sand material along the road (Gosz, 1974).

CONCLUSIONS

The Santa Fe Ski Basin and its sanitary sewage disposal system did not contribute significantly to the total bacterial counts in samples taken below the ski basin. This does not indicate that there was no human pollution, nor that there was no threat to the health of any subsequent users of the water. The potential impact could only be determined by speciation of bacterial colonies isolated from the streams at each of the three areas. This speciation could determine whether the source was human fecal contamination, or fecal contamination from other mammals or other sources. However, in light of the very low number of colonies found in the stream, any impact found by speciation could be purely academic.

The analyses of the snowpack associated with the automobile activity of the ski basin did not reveal any significant impact except on the samples taken radiating out from the parking lot with distance and direction. The strong trend seen in the

samples radiating out with distance and direction from the parking lot, however, suggests that over longer periods of time there is a potential for impact due to heavy metals. Considering the significant values found between the Usnea samples collected at control and roadside locations, the potential for harm to the surrounding vegetation does seem to exist. Looking at Table 24 one can see that in the 1975-76 water year there was a net gain of 36 g/ha Zn, 40 g/ha Pb, and 22.7 g/ha Cu in Area 1 or the control area for the Santa Fe Ski Basin. These annual budgets are based only upon the inputs measured in the snowpack and do not take into consideration any input contributed by rain samples during the rest of the year, and therefore are an underestimate of the total input. Perhaps other years would not show a net gain or would even show a net removal of heavy metals from the area, but the increase shown in this one year merits further investigation.

Stream samples below the ski basin were significantly higher in heavy metal and particulate content than at Area 1. This was due to the higher particulate loss associated with ski basin activities. Bormann, Likens, and Eaton (1969) found the biotic community greatly controlled particulate and solution losses from a forest ecosystem. At the Santa Fe Ski Basin, revegetation of the roads in the distrubed areas associated with the ski basin would perhaps minimize or at least reduce the losses of the particulate matter from the ski basin and therefore reduce the total transport of heavy metals.

Earlier work performed on the Santa Fe Ski Basin (Gosz, 1975) found that the inorganic chemistry of the areas below the ski basin was primarily controlled by road salt. Figure 6 demonstrates the shift in inorganic constituents below Areas 2 and 3. The trilinear plot shows the shift toward the road salt concentrations and not toward the sewage concentrations for the inorganic constituents. The predominance towards road salt and not towards sewage effluent along with the bacteriological data collected during this study supports the hypothesis that the sewage facilities of the Santa Fe Ski Basin are not deteriorating the water quality, either chemically or bacteriologically, of the stream associated with the area.

The degree of deterioration in the heavy metal aspects of water quality due to the road salting has not been determined. The road salt and associated activities could potentially contribute to the particulate loss noted below Area 2.

Suggestions for Future Management of the Santa Fe Ski Basin

Control of particulate mineral loss from the Santa Fe Ski Basin should be of primary interest. Revegetation of all the exposed soils should provide the adequate regulatory mechanism for prevention of particulate losses from the Santa Fe Ski Basin. The effects of road salt upon the particulate loss and also the heavy metal loss should be studied further to determine if there is any impact. Feick, Horne, Yeaple (1972) found Hg to be released from contaminated fresh water sediments by road deicing

salt. Such release of Zn, Pb, and Cu could be possible by the road deicing salts applied at the Santa Fe Ski Basin.

The sewage treatment facilities at the Santa Fe Ski Basin at this time are adequate so that no deterioration in water quality, either chemical or bacteriological, can be detected. If the trend for higher usage of the ski basin continues, sewage treatment facilities may have to be improved to maintain current conditions.

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Table 1. Total coliform bacteria of stream water collections from three areas of the Santa Fe Ski Basin

	Site								
	Area 3			Area 2			Area 1		
	Replicates[1]			Replicates			Replicates		
Date	1	2	3	1	2	3	1	2	3
6/26/75	332	238	260	128	204	182	30	35	40
7/10/75	156	148	160	212	200	176	45.6	40.8	44
7/24/75	22	23	27	9	18	18	94	133	125
8/6/75	76	76	76	56	76	66	9	11	10
8/28/75	63.2	65.6	68	43.2	40	42.4	4.8	4.8	3.2
9/8/75	21.6	24	18.4	8.8	13.6	18.4	5.6	8.8	10.4
9/22/75	84.8	88	76	69.6	79.2	71.2	9.6	12.8	-
10/6/75	74.4	42.4	68	TMTC*	TMTC	TMTC	72.8	11.2	16.8
10/20/75	13.6	14.4	10.4	1.6	4	2.4	34.4	26.4	30.4
11/3/75	6.4	3.2	7.2	7.2	4	6.4	34.4	20	32
11/17/75	0	0	TMTC	8.8	TMTC	20	8.8	8.8	66.4
12/8/75	4	4.8	4.8	8.8	16	10.4	0.8	0	0
1/6/76	5.6	7.2	5.6	8.8	6.4	9.6	0	0	0
2/4/76	0.8	0	0.8	0	0.8	0.8	0	0	0
3/1/76	0	0	0	0.8	0	2.4	0	0	0
4/5/76	0	0	0	4	4	0	0	0	0
4/26/76	0	0	0	0	0	0	0	0	0
5/11/76	0	0	10	0	0	0	0	0	0
5/24/76	0	0	0	0	4	0	0	0	0
6/7/76	16	12.8	13.6	38.4	48.8	6.08	10.4	8	8.8
6/21/76	0	4	4	0	0	0	0	0	0

[1] Values are expressed as per 100 ml of sample.

* For statistical purposes, 150 was substituted for all replicates that were too many to count (TMTC).

Table 2. Fecal coliform bacteria of stream water collections from three areas of the Santa Fe Ski Basin

	Site								
	Area 3			Area 2			Area 1		
	Replicates[1]			Replicates			Replicates		
Date	1	2	3	1	2	3	1	2	3
9/8/75	2.4	1.6	5.6	3.2	2.4	1.6	2.4	6.4	4
9/22/75	0	0	0	0	0	0	0	0	0
10/6/75	0	0	0	0	0	0	0	0	0
10/20/75	0	0	0	0	0	0	0	0	0
11/3/75	0.8	0.8	1.6	4	1.6	0.8	29.6	19.2	33.6
11/17/75	0	0	0	2.4	2.4	3.2	1.6	0.8	0
12/8/75	0	0	0	0	0	0.8	0	0.8	0
1/6/76	0	0	0	0	2.4	0	0	0.8	0
2/4/76	0	0	0	0	0	0	0	0	0
3/1/76	0	0	0	0	0	0	0	0	0
4/5/76	0	0	0	0	0	0	0	0	0
4/26/76	0	0	0	0	0	0	0	0	0
5/11/76	0	0	0	0	0	0	0	0	0
5/24/76	0	0	0	0	0	0	0	0	0
6/7/76	0	0	0	0	0	0	0	0	0
6/21/76	0	0	0	0	0	0	0	0	0

[1] Values are expressed as per 100 ml of sample.

Table 3. Fecal streptococci bacteria of stream water collections from three areas of the Santa Fe Ski Basin

	Site								
	Area 3			Area 2			Area 1		
	Replicates[1]			Replicates			Replicates		
	1	2	3	1	2	3	1	2	3
9/8/75	40.8	67.2	-	21.6	50.4	23.2	48	31.2	59.2
9/22/75	2.4	7.2	4	83.2	48.8	40	5.6	8	8.8
10/6/75	4.8	10.4	8	12	17.6	7.2	12.8	15.2	11.2
10/20/75	0	1.6	0	4	2.4	3.2	0.8	0.8	8
11/3/75	14.4	0.8	0.8	80.8	71.2	84.8	18.4	36.8	17.6
11/17/75	8.8	12.8	8.8	17.6	10.4	13.6	49.6	0.8	3.2
12/8/75	16.8	9.6	11.2	19.2	12	12.8	59.2	40	70.4
1/6/76	2.4	0.8	1.6	0.8	1.6	1.6	0	0	0
2/4/76	0	0	0	0	0	0	0.8	2.4	0
3/1/76	6.4	24.8	6.4	4.8	0.8	19.2	7.2	3.2	8
4/5/76	0	4	4	24	20	24	0	0	4
4/26/76	4	8	0	12	15	12	4	0	0
5/11/76	20	20	0	0	0	20	4	12	16
5/24/76	4	8	8	8	44	4	32	20	24
6/7/76	0.8	1.6	0	2.4	1.6	0	1.6	0	0
6/21/76	8	8	0	0	0	4	4	12	8

[1] Values are expressed as per 100 ml sample.

Table 4. Analysis of Variance for bacteriological analyses

Bacterial Group	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value
Total Coliform	Site	24456.0	2	12228.0	35.8*
	Date	358638.9	20	17931.9	52.5*
	Site x Date	172143.8	40	4303.6	12.6 *
	Error	43051.3	126	341.7	
	Total	598289.9	188		
Fecal Coliform	Site	91.3	2	45.6	30.9*
	Date	921.3	15	61.4	41.6*
	Site x Date	1266.2	30	42.2	28.6*
	Error	141.6	96	1.5	
	Total	2420.4	143		
Fecal Streptococci	Site	1942.5	2	971.3	12.9*
	Date	22992.2	15	1532.8	20.3*
	Site x Date	18540.9	30	618.0	8.2*
	Error	7251.5	96	75.5	
	Total	50727.2	143		

* Significant at $P \leq 0.05$

Table 5. Duncan's New Multiple-Range Test for bacteriological analyses: Site and bacterial group. Means with X in same column with . indicate a significant difference

Bacterial Group	Site	Rank No.	Mean	Area 3	Area 2	Area 1
Total Coliform	Area 3	1	41.073	.		
	Area 2	2	36.676		.	
	Area 1	3	17.127	X	X	.
Fecal Coliform	Area 3	3	0.267	.		
	Area 2	2	0.517		.	
	Area 1	1	2.067	X		.
Fecal Streptococci	Area 3	3	8.858	.		
	Area 2	1	17.829	X	.	
	Area 1	2	13.983			.

Table 6. Duncan's New Multiple-Range Test for bacteriological analyses: Date and total coliform. Means with X in same column with . indicate a significant difference

Date	Date No.	Rank	Mean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
6/26/75	1	1	161.	.																				
7/10/75	2	2	131.38		.																			
7/24/75	3	5	52.11	X	X	.																		
8/6/75	4	6	50.67	X	X		.																	
8/28/75	5	8	37.24	X	X			.																
9/8/75	6	11	14.4	X	X				.															
9/22/75	7	4	55.82	X	X					.														
10/6/75	8	3	81.73	X	X			X	X		.													
10/20/75	9	10	15.29	X	X						X	.												
11/3/75	10	12	13.42	X	X						X		.											
11/17/75	11	7	45.87	X	X									.										
12/8/75	12	13	5.51	X	X	X	X			X	X				.									
1/6/76	13	14	4.8	X	X	X	X			X	X					.								
2/4/76	14	20	0.31	X	X	X	X			X	X			X			.							
3/1/76	15	19	0.36	X	X	X	X			X	X			X				.						
4/5/76	16	17	0.89	X	X	X	X			X	X			X					.					
4/26/76	17	21	0.0	X	X	X	X			X	X			X						.				
5/11/76	18	15	1.11	X	X	X	X			X	X			X							.		.	
5/24/76	19	18	0.44	X	X	X	X			X	X			X								.		
6/7/76	20	9	24.18	X	X						X												.	
6/21/76	21	16	0.89	X	X	X	X			X	X			X										.

Table 7. Duncan's New Multiple-Range Test for bacteriological analyses: Date and fecal coliform. Means with X in same column with . indicate a significant difference

Date	Date No.	Rank	Mean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9/8/75	1	2	3.29	.															
9/22/75	2	16	0.0		.														
10/6/75	3	15	0.0			.													
10/20/75	4	14	0.0				.												
11/3/75	5	1	10.22	X	X	X	X	.											
11/17/75	6	3	1.16					X	.										
12/8/75	7	5	0.18					X		.									
1/6/76	8	4	0.36					X			.								
2/4/76	9	13	0.0					X				.							
3/1/76	10	12	0.0					X					.						
4/5/76	11	11	0.0					X						.					
4/26/76	12	10	0.0					X							.				
5/11/76	13	9	0.0					X								.			
5/24/76	14	8	0.0					X									.		
6/7/76	15	7	0.0					X										.	
6/21/76	16	6	0.0					X											.

Table 8. Duncan's New Multiple-Range Test for bacteriological analyses: Date and fecal streptococci. Means with X in same column with . indicate a significant difference.

Date	Date No.	Rank	Mean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
9/8/75	1	1	43.96	.															
9/22/75	2	4	23.11	X	.														
10/6/75	3	8	11.02	X		.													
10/20/75	4	13	2.31	X	X		.												
11/3/75	5	2	36.18			X	X	.											
11/17/75	6	6	13.96	X				X	.										
12/8/75	7	3	27.91	X		X	X			.									
1/6/76	8	15	0.98	X	X			X		X	.								
2/4/76	9	16	0.36	X	X			X		X		.							
3/1/76	10	9	8.89	X				X		X			.						
4/5/76	11	11	7.11	X				X		X				.					
4/26/76	12	10	7.44	X				X		X					.				
5/11/76	13	7	11.56	X				X		X						.			
5/24/76	14	5	16.00	X				X									.		
6/7/76	15	14	1.51	X	X			X		X								.	
6/21/76	16	12	5.16	X	X			X		X									.

Table 9. Monthly total car and bus count at Santa Fe Ski Basin, 1975-1976 ski season*

Month	Total Cars	Busses
December, 1975	5810	18
January, 1976	5455	59
February, 1976	5891	100
March, 1976	4648	93
April, 1976	230	0

* Based upon data obtained from U. S. Forest Service, Santa Fe National Forest.

Table 10. Average skiers per day at the Santa Fe Ski Basin*

Season	Skier Visits	Ski Season Length in days	Average Skiers per day
63-64	21,278	144	147
64-65	28,371	145	195
65-66	26,458	128	206
66-67	24,610	119	206
67-68	30,272	120	252
68-69	31,956	116	275
69-70	34,101	115	296
70-71	34,395	137	251
71-72	30,000	106	283
72-73	45,402	121	375
73-74	67,947	156	371
74-75	56,977	130	438
75-76	63,691	138	461

* Based upon data obtained from U. S. Forest Service, Santa Fe National Forest.

Table 11. Heavy metal and particulate matter content in snowpack at Santa Fe Ski Basin

Location	Date	Particulate Matter (kg/ha)	ZINC			LEAD			COPPER		
			Filtrate (ug/l)	Particulate (ug/l)	Total (g/ha)	Filtrate (ug/l)	Particulate (ug/l)	Total (g/ha)	Filtrate (ug/l)	Particulate (ug/l)	Total (g/ha)
A	12/2/75	28.8	0	4.76	4.00	0.1	5.14	4.32	1.4	2.76	3.49
	1/6/76	-	1	5.96	7.45	1.5	13.19	15.72	0.1	3.35	3.58
	2/3/76	52.0	3	-	-	1.8	13.39	15.80	1.5	4.52	6.26
	3/11/76	139.9	1	18.92	41.62	2.8	16.12	41.62	0.7	10.28	24.16
B	12/2/75	36.0	1	2.77	3.17	0.1	7.96	6.69	0.6	3.04	3.06
	1/6/76	42.5	1	6.96	5.09	4.5	46.36	32.55	0.1	15.68	10.04
	2/3/76	119.8	5	-	-	6.8	33.60	45.25	1.3	4.50	6.50
	3/11/76	25.26	1	17.84	26.40	4.5	34.32	57.45	0.9	9.66	15.63
C	12/2/76	42.9	3	11.46	11.88	0.1	9.58	9.68	1.6	4.04	5.70
	1/6/76	53.6	0	6.61	6.94	3.5	26.43	31.43	0.1	4.68	4.91
	2/3/76	77.6	2	-	-	3.1	14.94	19.30	1.3	4.44	6.14
	3/11/76	-	1	13.43	21.63	5.4	20.72	42.05	0.9	8.76	15.55
D	12/2/76	58.1	4	5.19	10.29	0.1	17.04	19.08	1.8	3.62	6.07
	1/6/76	69.0	3	7.83	11.70	2.2	39.35	44.87	1.4	7.17	9.26
	2/3/76	129.8	1	-	-	4.3	57.89	76.49	1.0	8.74	11.98
	3/11/76	323.3	1	18.75	39.94	3.1	35.46	82.13	0.9	8.57	20.17
E	12/2/76	48.9	3	7.12	10.63	0.1	5.00	5.25	1.0	3.35	4.57
	1/6/76	-	0	9.38	9.76	0.4	20.75	22.84	0.1	5.04	5.24
	2/3/76	80.8	5	-	-	1.4	8.03	10.00	1.5	3.83	5.65
	3/11/76	233.2	1	13.60	23.12	2.8	16.92	33.52	1.2	10.28	19.52
Control In Open	1/13/76	62.3	3	3.22	16.48	2.2	6.10	22.00	1.3	1.90	8.48
	2/27/76	146.4	7	5.37	49.85	1.3	11.22	50.46	0.6	3.07	14.79
	4/1/76	274.7	1	8.90	38.00	1.4	23.00	104.19	0.5	5.77	26.77
Control Under Trees	1/13/76	117.0	6	9.72	15.56	3.5	14.45	17.77	1.6	4.55	6.09
	2/27/76	353.0	1	4.60	10.92	1.4	13.27	28.61	0.7	3.77	8.72
	4/1/76	335.1	1	17.80	36.13	1.0	46.25	95.92	0.6	13.36	28.34

Table 12. Analysis of Variance of heavy metal content of snowpack from the Santa Fe Ski Basin and controls

Metal	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value
Zinc	Area	1088.68	6	181.447	0.87
	Error	2912.84	14	208.060	
	Total	4001.52	20		
Lead	Area	5506.96	6	916.827	1.40
	Error	9186.27	14	656.162	
	Total	14693.23	20		
Copper	Area	137.01	6	22.834	0.31
	Error	1025.43	14	73.245	
	Total	1162.44	20		

Table 13. Duncan's New Multiple-Range Test for heavy metal content of snowpack from the Santa Fe Ski Basin and controls. Mean with X in same column with . indicate a significant difference

Metal	Site	Rank No.	Mean	Site A	B	C	D	E	Control Open	Control Trees
Zinc	A	4	17.68	.						
	B	7	11.55		.					
	C	6	13.48			.				
	D	3	20.64				.			
	E	5	14.50					.		
	Control Open	1	34.78						.	
	Control Trees	2	20.87							.
Lead	A	6	24.38	.						
	B	4	45.08		.					
	C	5	30.93			.				
	D	1	68.16				.			
	E	7	22.12					.		
	Control Open	2	58.88						.	
	Control Trees	3	47.43							.
Copper	A	4	11.33	.						
	B	5	10.70		.					
	C	7	8.87			.				
	D	3	13.80				.			
	E	6	10.14					.		
	Control Open	1	16.68						.	
	Control Trees	2	14.38							.

Table 14. Heavy metal and particulate content of snowpack with distance and direction from parking lot (March 16, 1976)

From Parking Lot		Total Particulate Matter	ZINC			LEAD			COPPER		
Direction	Dist. (ft.)	(kg/ha)	Filtrate (µg/l)	Particulate (µg/l	Total (g/ha)	Filtrate (µg/l	Particulate (µg/l)	Total (g/ha)	Filtrate (µg/l)	Particulate (µg/l	Total (g/ha)
	0	319	4	17.6	58.97	4.1	40.5	121.76	0.3	7.88	22.33
	190	165	1	10.9	24.18	2.1	15.8	36.37	0.4	5.93	12.86
East	380	198	0	11.68	23.73	1.9	15.2	34.75	0.1	6.25	12.90
	570	92	0	9.8	21.95	4.5	20.2	55.33	0.0	4.75	10.64
	0	239	-	9.5	26.54	-	21.6	60.35	-	6.15	17.18
	190	195	0	9.4	25.87	2.0	18.7	56.97	0.1	5.78	16.18
North	380	182	7	11.3	40.26	1.3	20.4	47.74	1.0	6.96	17.51
	570	247	0	10.7	22.83	1.5	13.2	31.36	0.4	6.25	14.19
	0	311	0	7.0	33.56	1.9	15.9	85.33	0.3	4.95	25.17
	190	269	0	14.7	32.66	2.6	33.6	80.44	0.4	8.1	18.89
West	380	182	0	9.1	19.26	1.8	15.1	35.78	0.1	7.0	14.82
	570	316	3	16.2	35.33	1.8	11.8	25.02	0.1	6.76	12.44
	0	357	0	11.6	42.24	1.4	18.7	73.18	1.1	8.06	33.35
	190	235	0	11.4	23.53	1.0	17.9	39.01	0.3	9.73	20.70
South	380	204	0	10.8	20.57	1.8	14.6	31.24	0.1	7.67	14.8
	570	266	0	12.9	29.21	1.8	17.9	40.03	0.1	6.93	14.3

Table 15. Analysis of Variance of heavy metal and particulate matter content of snowpack with direction and distance from parking lot

Components	Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Value
Direction and Metals	Direction	202.59	3	67.53	0.2136
	Metals	10688.91	2	5344.46	16.906*
	Direction x Metals	550.79	6	91.80	0.2904
	Error	11380.68	36	316.13	
	Total	22822.97	47		
Distance and Metals	Distance	4607.89	3	1535.96	10.55*
	Metals	10700.61	2	5350.30	36.75*
	Distance x Metals	2285.41	6	380.90	2.62*
	Error	5240.78	36	145.58	
	Total	22834.69	47		
Direction and Particulate Matter	Direction	16835.19	3	5611.73	1.23
	Error	54597.75	12	4549.81	
	Total	71432.94	15		
Distance and Particulate Matter	Distance	29534.19	3	9844.73	2.82**
	Error	41898.75	12	3491.56	
	Total	71432.94	15		

* Significant at $P \leq 0.05$
** Significant at $P \leq 0.10$

Table 16. Duncan's New Multiple-Range Test for heavy metal and particulate matter content of snowpack with direction from parking lot. Means with X in same column with . indicate a significant difference

Metal	Direction (ft.)	Rank	Mean	Direction E	N	W	S
Zinc	East	1	32.21	.			
	North	4	28.87		.		
	West	2	30.20			.	
	South	3	28.89				.
Lead	East	1	62.05	.			
	North	4	49.10		.		
	West	3	56.64			.	
	South	2	58.36				.
Copper	East	4	14.68	.			
	North	3	16.26		.		
	West	2	17.83			.	
	South	1	20.79				.
Particulate Matter	East	4	193.50	.			
	North	3	215.75		.		
	West	1	269.50			.	
	South	2	265.50				.

Table 17. Duncan's New Multiple-Range Test for heavy metal and particulate matter content of snowpack with distance from parking lot. Means with X in same column with . indicate a significant difference.

Metal	Distance (ft.)	Rank	Mean	Distance 0	190	380	570
Zinc	0	1	40.33	.			
	190	3	26.56		.		
	380	4	26.95			.	
	570	2	27.33				.
Lead	0	1	85.155	.			
	190	2	53.20	X	.		
	380	4	37.38	X		.	
	570	3	37.94	X			.
Copper	0	1	24.51	.			
	190	2	17.16	X	.		
	380	3	14.92	X		.	
	570	4	12.89	X			.
Particulate Matter	0	1	306.5	.			
	190	3	216.0		.		
	380	4	191.5	X		.	
	570	2	230.25				.

Table 18. Heavy metal content of Usnea concentrations expressed as sample % of dry weight

		[Manganese]	[Zinc]	[Lead]	[Copper]	$\frac{[\text{Lead}]}{[\text{sum all metals}]}$
Control Area Samples	#1	0.0094	0.0049	0.0027	0.00188	0.143
	#2	0.0114	0.0046	0.0040	0.00108	0.1897
	#3	0.0117	0.0048	0.0037	0.00121	0.1728
	$\bar{X}$	0.01083	0.00476	0.00346	0.00139	0.1685
	Std. Dev.	0.00125	0.00015	0.00068	0.00042	0.0236
Roadside Area Samples	#1	0.0095	0.0037	0.0069	0.00086	0.3292
	#2	0.0072	0.0035	0.0059	0.00092	0.3368
	#3	0.0064	0.0024	0.0048	0.00088	0.3315
	$\bar{X}$	0.0077	0.0032	0.00587	0.00088	0.3325
	Std. Dev.	0.0016	0.0007	0.00105	0.00003	0.0039
	*t-value	+2.63	+3.38	-3.37	+2.23	-10.30

* Critical Value for t-distribution, d. f. = 2, $P \leq .05$, $t = 4.303$

Note - t-test performed on arcsine transformed data

Table 19. Weighted average concentrations of stream constituents measured at the three areas of the Santa Fe Ski Basin for the 1975-76 water year

Constituents	Area 1	Area 2	Area 3
Particulate Matter (mg/l)	2.056	17.223	9.20
Organic N (mg/l)	0.234	0.262	0.288
Organic N/Particulate Matter	0.1138	0.0152	0.0312
Zn (µg/l)	1.354	7.572	7.013
Zn/Zn + Pb + Cu	0.639	0.758	0.826
Zn/Particulate Matter (µg/mg)	6.59×10^{-4}	4.4×10^{-4}	7.62×10^{-4}
Pb (µg/l)	0.399	1.129	0.730
Pb/Zn + Pb + Cu	0.188	0.103	0.086
Pb/Particulate Matter (µg/mg)	1.94×10^{-4}	0.65×10^{-4}	0.79×10^{-4}
Cu (µg/l)	0.367	1.416	0.7476
Cu/Zn + Pb + Cu	0.173	0.139	0.088
Cu/Particulate Matter (µg/mg)	1.78×10^{-4}	0.82×10^{-4}	0.81×10^{-4}

Table 20. Annual exports for particulate matter, organic-N, Zn, Pb, and Cu for the three areas at the Santa Fe Ski Basin for the 1975-76 water year

Constituents	Area 1	Area 2	Area 3
Particulate Matter (kg/ha)	8.36	64.85	-545.51
Organic-N (kg/ha)	0.952	0.938	2.804
Zn (g/ha)	5.520	28.66	-16.47
Pb (g/ha)	1.625	3.88	-26.21
Cu (g/ha)	1.501	5.26	-45.51

Table 21. Correlation table for total particulate matter (TPM), and filtrate (F), particulate (P), and total (T) heavy metals found at Area 1 for the 1975-76 water year

		TPM	Zn			Pb			Cu		
			F	P	T	F	P	T	F	P	T
TPM		1.00									
Zn	F	-0.154	1.00								
	P	0.218	0.031	1.00							
	T	-0.020	0.866*	0.527*	1.00						
Pb	F	-0.096	0.020	0.080	0.057	1.00					
	P	0.205	-0.082	0.361*	0.110	-0.083	1.00				
	T	-0.050	-0.020	0.156	0.080	0.978*	0.129	1.00			
Cu	F	0.727*	-0.030	0.062	0.0048	-0.040	-0.040	-0.050	1.00		
	P	-0.050	0.163	0.553*	0.415*	0.643*	0.164	0.674*	-0.157	1.00	
	T	0.695*	0.033	0.277	0.167	0.209	0.021	0.212	0.922*	0.236	1.00

* Significant at $P \leq 0.05$ level, critical value is $\pm$ 0.349.

Table 22. Correlation table for total particulate matter (TPM), and filtrate (F), particulate (P), and total (T) heavy metals found at Area 2 for the 1975-76 water year

			Zn			Pb			Cu		
		TPM	F	P	T	F	P	T	F	P	T
TPM		1.00									
Zn	F	0.094	1.00								
	P	0.934*	0.153	1.00							
	T	0.869*	0.461*	0.947*	1.00						
Pb	F	-0.040	0.164	-0.020	0.040	1.00					
	P	0.951*	0.101	0.935*	0.872*	-0.020	1.00				
	T	0.772*	0.177	0.774*	0.752*	0.547*	0.828*	1.00			
Cu	F	0.769*	0.046	0.750*	0.689*	-0.020	0.895*	0.739*	1.00		
	P	0.976*	0.051	0.892*	0.817*	0.034	0.959*	0.822*	0.811*	1.00	
	T	0.924*	0.051	0.868*	0.796*	0.010	0.977*	0.823*	0.958*	0.796*	1.00

* Significant at $P \leq 0.05$ level, critical value is $\pm$ 0.349.

Table 23. Correlation table for total particulate matter (TPM), and filtrate (F), particulate (P), and total (T) heavy metals found at Area 3 for the 1975-76 water year

			Zn			Pb			Cu		
		TPM	F	P	T	F	P	T	F	P	T
TPM		1.00									
Zn	F	-0.230	1.00								
	P	0.906*	-0.176	1.00							
	T	0.655*	0.488*	0.774*	1.00						
Pb	F	0.062	-0.135	0.073	-0.02	1.00					
	P	0.913*	-0.274	0.905*	0.626*	0.044	1.00				
	T	0.541*	-0.258	0.546*	0.318	0.844*	0.573*	1.00			
Cu	F	0.165	0.359*	0.165	0.378*	-0.172	0.084	-0.096	1.00		
	P	0.924*	-0.253	0.969*	0.697*	0.119	0.943*	0.604*	0.151	1.00	
	T	0.778*	0.017	0.812*	0.731*	-0.01	0.746*	0.393*	0.682*	0.393*	1.00

* Significant at $P \leq 0.05$ level, critical value is $\pm$ 0.349.

Table 24. Annual budget for heavy metals and particulate matter for Area 1 at the Santa Fe Ski Basin for the 1975-76 water year

	Input*	Export	Net
Particulate Matter (kg/ha)	139.9	8.36	131.5
Zn (g/ha)	41.62	5.52	36.100
Pb (g/ha)	41.62	1.62	40.0
Cu (g/ha)	24.16	1.50	22.66

* Input measured only in snowpack and is therefore an underestimate for total years.

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Figure 4. Trilinear plot of the relative percentages of Pb, Zn, and Cu in the snowpack samples taken with distance and direction from the lower parking lot at the Santa Fe Ski Basin during the winter of 1975-76.

Figure 5. Trilinear plot of the relative percentages of Pb, Zn, and Cu in Usnea samples taken at the control and roadside locations at the Santa Fe Ski Basin in 1975.

Figure 6. Trilinear plotting diagram for the interpretation of water quality. The lines represent the range of water quality characteristic for the three areas of the Santa Fe Ski Basin during a three year period.

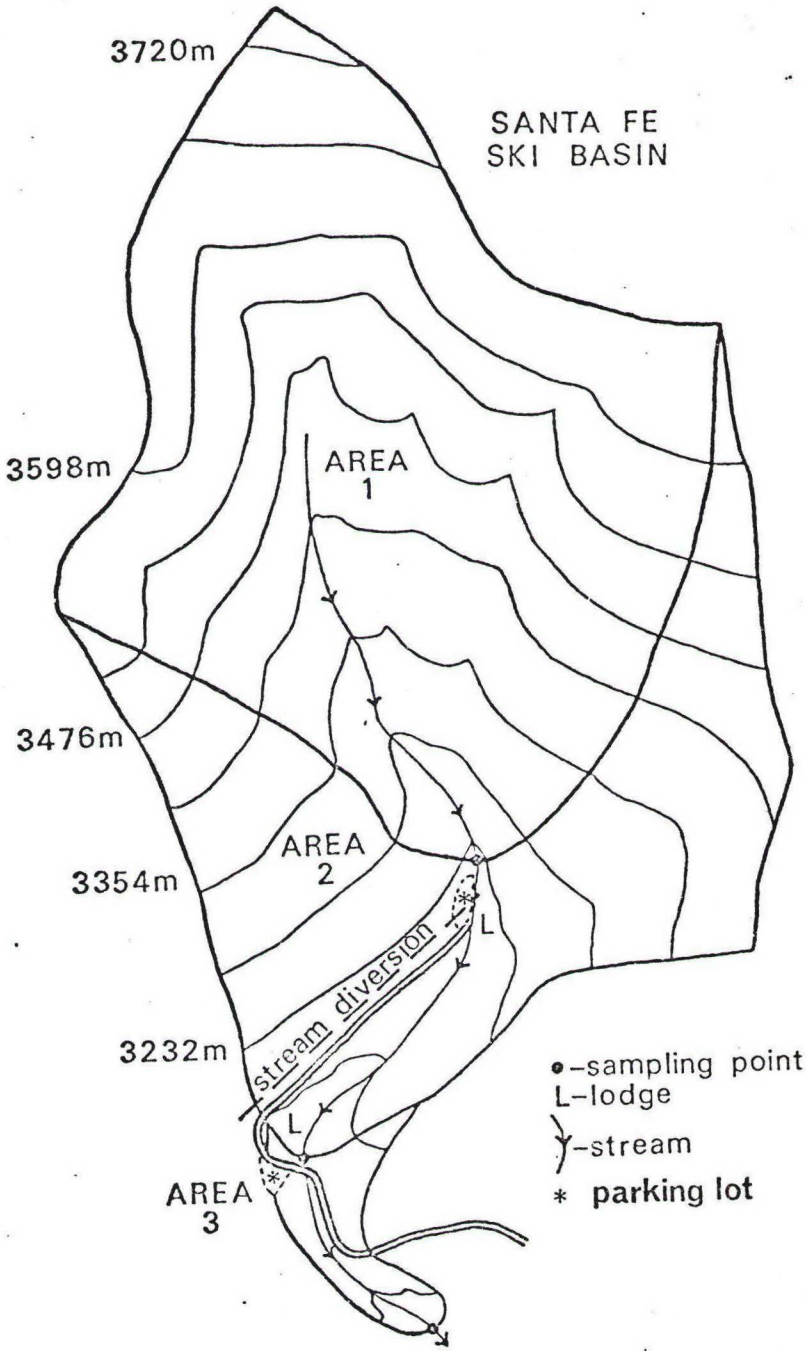
3720m
SANTA FE
SKI BASIN
3598m
AREA
1
3476m
AREA
2
3354m
L
Stream diversion
3232m
L
AREA
3
•-sampling point
L-lodge
-stream
* parking lot

Figure 1.

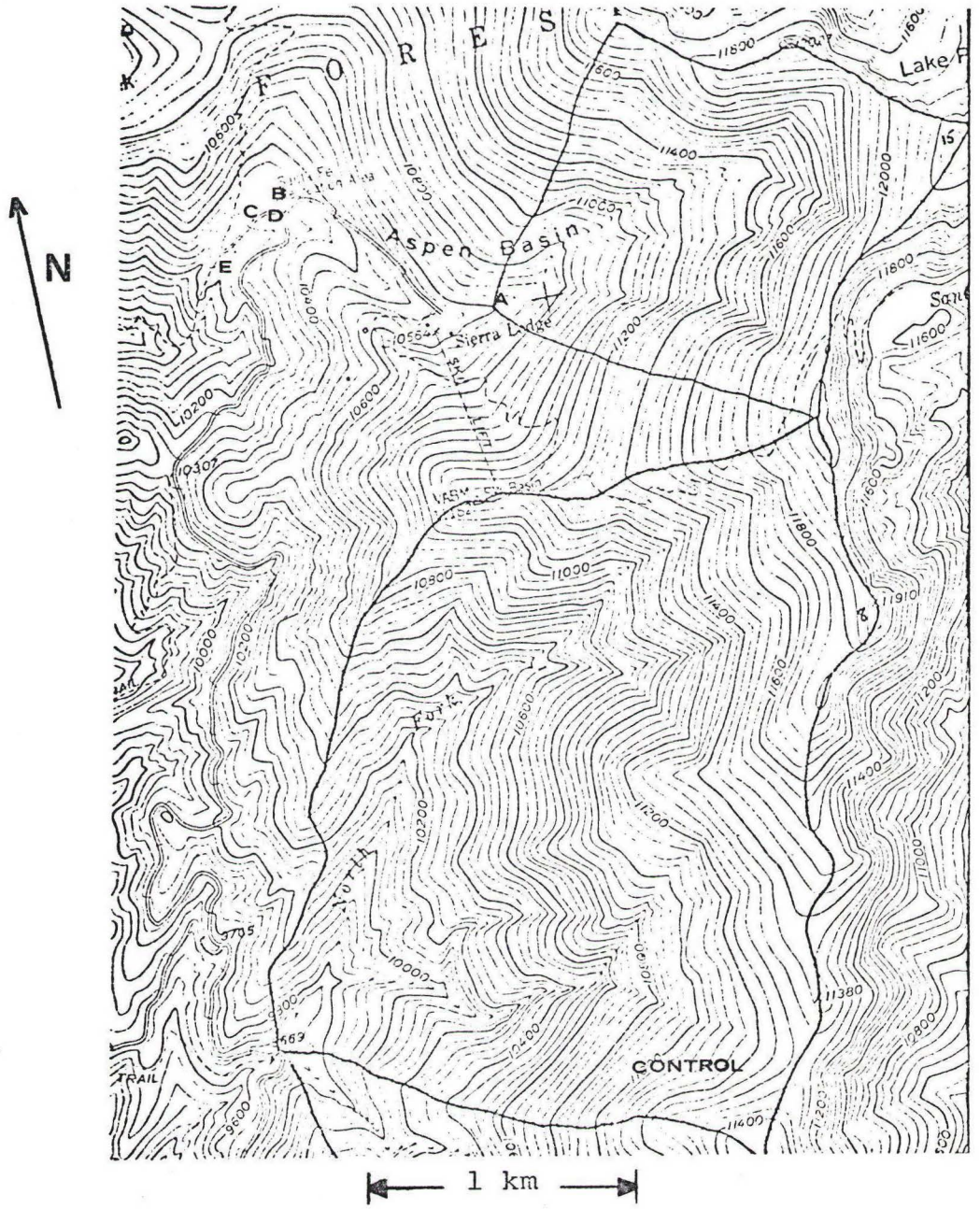

Figure 2.

Symbol	Site
A	A
B	B
C	C
D	D
E	E
0	Control-Open
T	Control-Tree

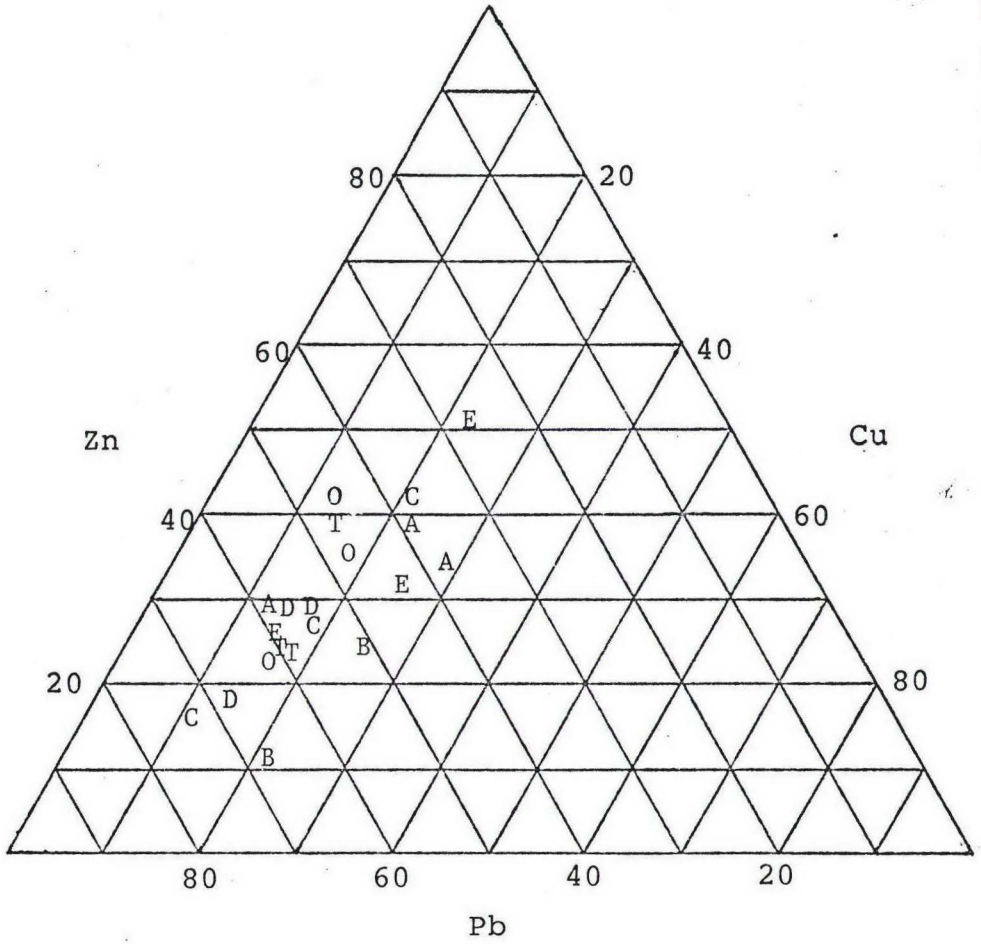

Figure 3.

Symbol	-	Direction
N	-	North
S	-	South
E	-	East
W	-	West

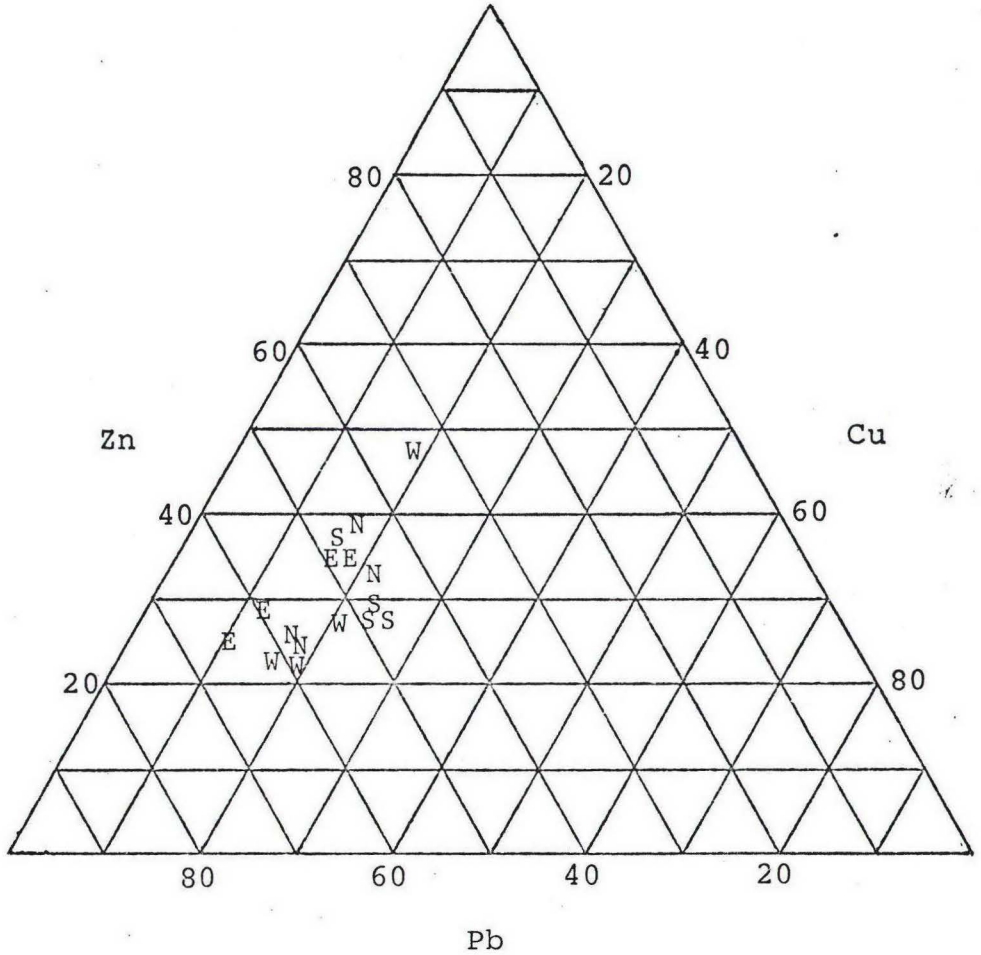

Figure 4.

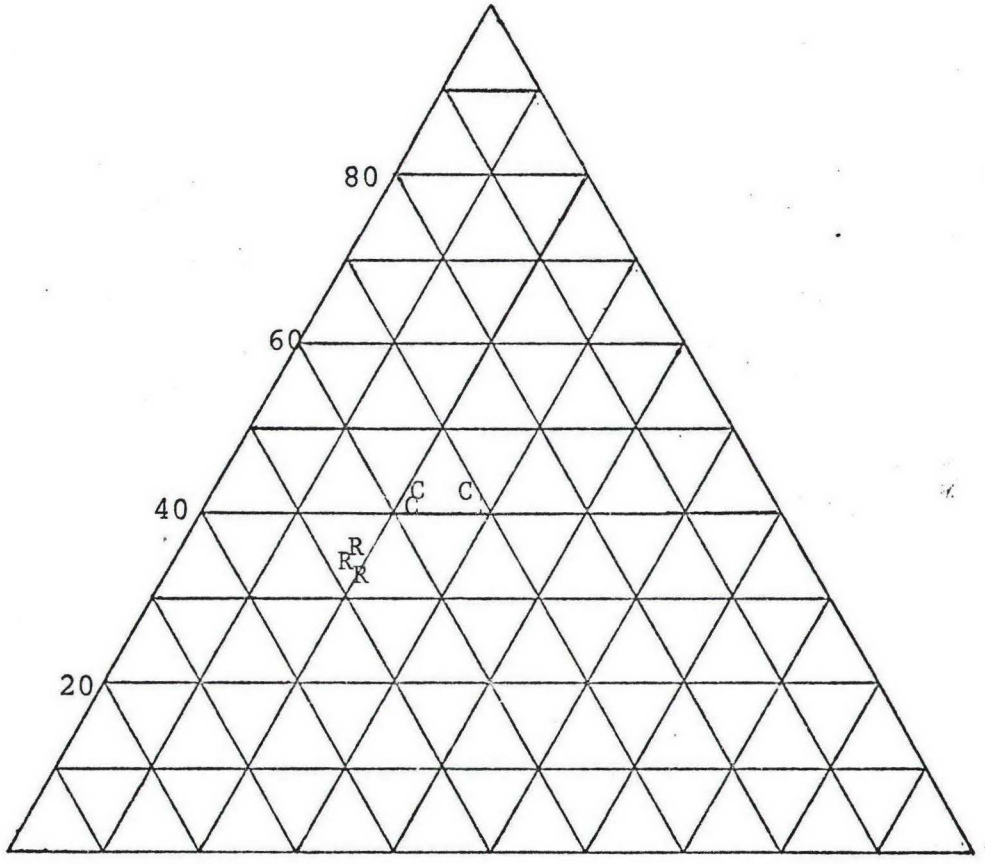

Figure 5.

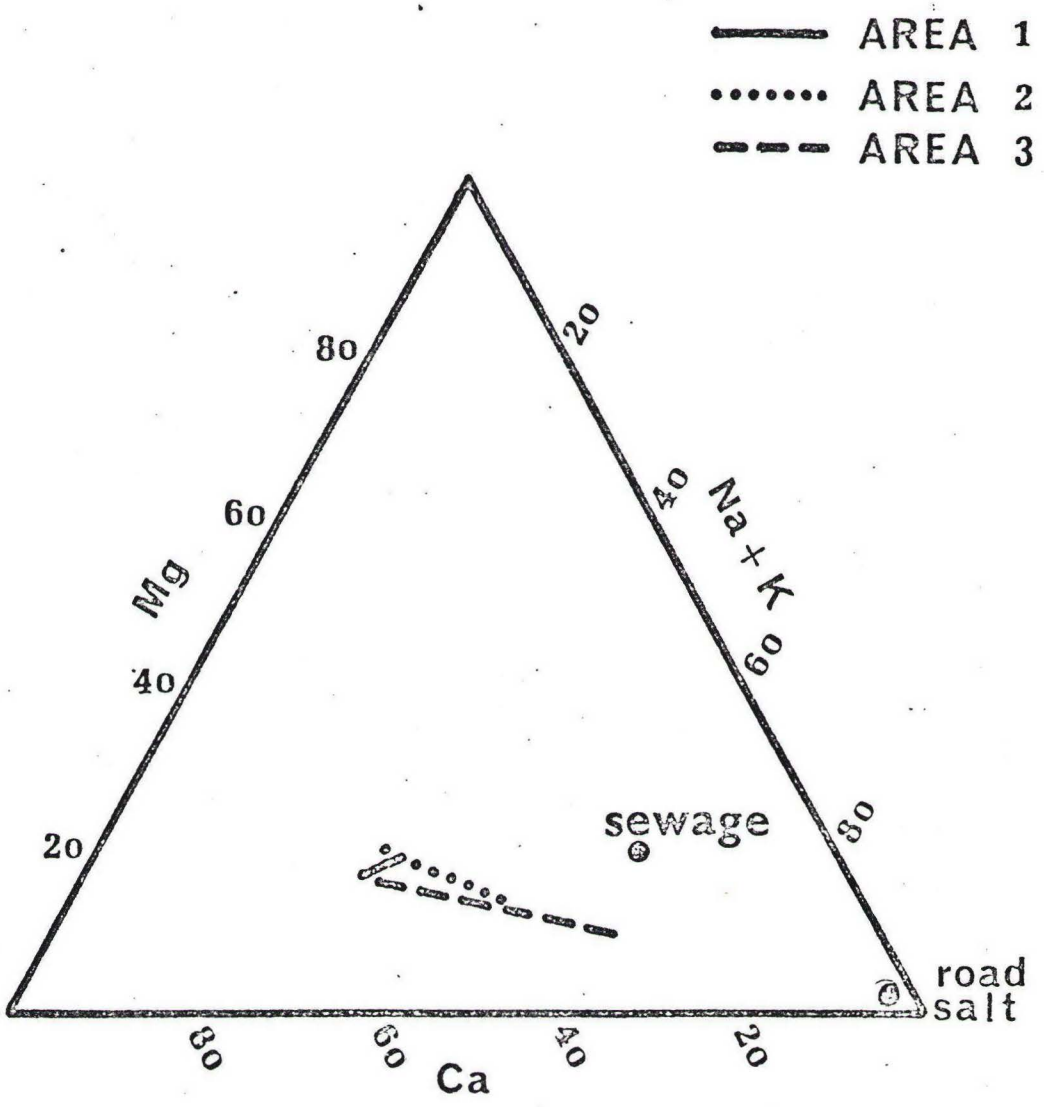
AREA 1
AREA 2
AREA 3
80
60
40
20
Mg
20
40
60
80
Na + K
sewage
road salt
80
60
40
20
Ca

Figure 6.

AD-33 Bookplate (1-63)

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